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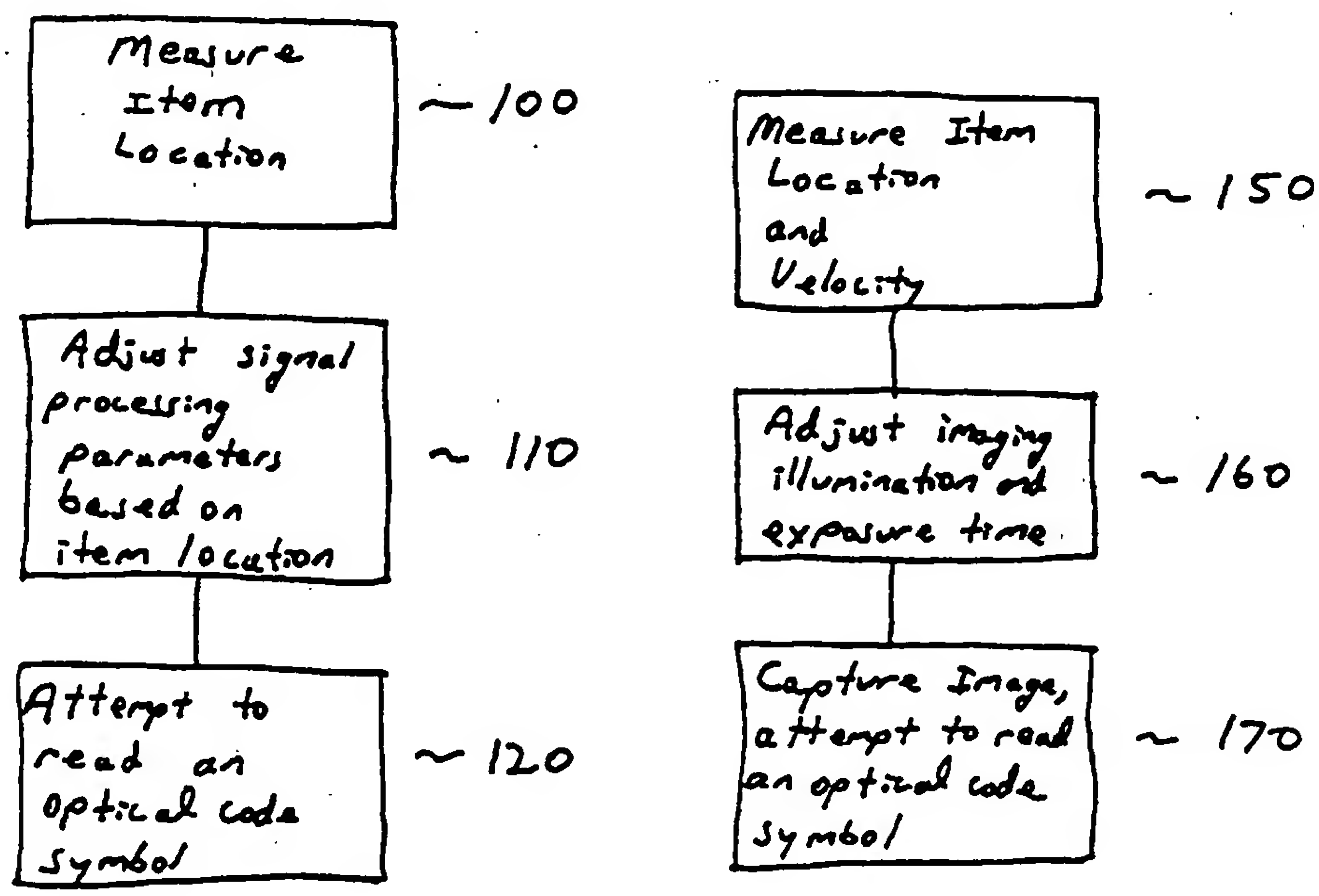
(54) Title: ADAPTIVE OPTICAL CODE READER USING OBJECT LOCATION AND MOVEMENT INFORMATION



(57) Abstract

A device and method which obtains movement and location information (100) of an optically coded item (20) located in a scan volume and uses the information to control operation of the reader (110). In one embodiment, the device includes a sensing apparatus (220) to measure the movement of an optically coded item (20) and an optical code reading apparatus (220) whose operation may be modified based on knowledge of that movement (150). Another embodiment is directed to a method which obtains data on the location and/or movement of an optically coded item (20) and then modifies the operation of the reader based on the data (120, 170).

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DESCRIPTION

Adaptive Optical Code Reader Using Object Location And Movement Information

Background of the Invention

The field of the present invention relates to devices for reading optical codes symbols, including conventional bar codes such as the UPC code, stacked bar codes such as PDF417, and matrix code symbols such as Maxicode. It is desirable for optical code reading devices to allow a range of positions and movements of the symbol relative to the reader, and for the reader to be insensitive to the surrounding environment, for ease of use and greater flexibility in installation and application of the reader. However, the performance of existing reader designs can be overly sensitive to the position and movement of the symbol relative to the reader, and performance can also be degraded by environmental factors, such as the visibility to the reader of printed or textured materials. These factors can reduce performance thereby lowering the productivity of the user, and possibly rendering the reader difficult or even impossible to use for some applications.

One approach to increasing the usefulness of optical symbol readers is to design several models, each model being optimized for use over part of the performance range of interest. This approach results in units that can work well in applications where a given user does not need to read symbols whose range of position or movement are large, but it is undesirable because the user or a supplier must understand the intended application well enough to select the appropriate unit, the manufacturer and distributors of reading devices must design, build, stock and service several models of readers, and finally, this solution does not help the user who must read symbols with

a large range of positions or movements at a single reading station.

Some reader designs have attempted to overcome these limitations by continuously adjusting a reader parameter. This approach can increase the range of performance of the reader with respect to the parameter being varied, but has the drawback of causing the reader to work poorly some portion of the time for a symbol which is located at an extreme of the usable range for the parameter being adjusted. For example, the preferred distance from reader to symbol can be adjusted to sweep the optimum read range in and out from the reader. This results in increasing the range of minimum reader to symbol distance to maximum reader to symbol distance, but at any particular instant, the reader will work well in part of that range, and poorly over the rest of the range. When a symbol is presented to the reader, some portion of the potential good reads of the symbol will be useless, and the time spent waiting for a good read may be a problem. If only a short time is available to read the symbol, as in the case of an item on a high speed conveyer, the reader must be able to cycle through its range of adjustments rapidly. For example, U.S. Patent No. 5,347,121 teaches a reader having the ability to rapidly vary the focus distance of the outgoing reading beam using LCD panels which are electrically controlled.

Another approach involves measuring range, i.e. the distance of the item bearing the symbol from the reader and adjusting the scanner appropriately. Such a system is disclosed in U.S. Patent No. 5,256,864. In that system, symbols on packages moving on conveyer belts detect the height of the package, and adjust the optical system in the reader to focus at the top surface of the package. This approach provides increased system performance with respect to read range (i.e. the distance from the scanner to the item), but may not address other performance

limiting factors such as relating to motion blur or differentiation of the item from the background.

Summary of the Invention

The present invention is directed to a device and method for determining movement and/or location information of an optically coded item and using the information to control operation of the reader. In one embodiment, the device comprises a sensing apparatus to measure the movement of an optically coded item and an optical code reading apparatus whose operation may be modified based on knowledge of that movement. Another embodiment is directed to a method which obtains data on the movement and/or location of an optically coded item and then modifies the operation of the reader based on the data.

Brief Description of the Drawings

Figure 1 illustrates a reader device and an optically coded item.

Figure 2 is a block diagram of an optical code reader including an item location sensor.

Figure 3 is a flow chart for a method of using item location information to control the operation of an optical code reader.

Figure 4 is a flow chart for a method of using item location and item movement information to control the imaging illumination and image exposure time in an optical code reader.

Figure 5 is a top right side perspective view of a multi-window scanner.

Figure 6 is a simplified schematic of example optic configuration for a multi-window scanner as in Figure 5.

Figure 7 is a simplified schematic of another example optical configuration for a multi-window scanner as in Figure 5.

Detailed Description of the Preferred Embodiment

Preferred embodiments of the present invention will now be described with respect to the drawings. As used herein, optical codes include, among others, conventional bar codes such as the omnipresent UPC code, stacked bar codes such as PDF 417, and matrix code symbols such as Maxicode. Also as used herein, an optical code scanner comprises an optical code reading device such as laser scanners employing one or more flying spot reading beams, CCD readers, readers using LEDs (light emitting diodes), or the like.

Figure 1 shows an optical code reader 10 and a coded item 20. The item 20 moves relative to the reader 10. This movement may be accomplished by placing the item on a conveyer belt which passes near the reader, by manually moving the item near a stationary reader, by aiming a hand held reader at a stationary item, or by any other means appropriate to the application at hand.

Figure 2 shows an optical code reader apparatus 10 which includes an item location and movement sensor 50 to measure the location and movement of coded item 20 relative the reader 10, a control function apparatus 60 which uses the output of the sensor 50, and a reader head 70 whose operation is affected by the output of the control function apparatus 60.

Item position and movement sensor 50 may be comprised of a radar device which detects both the distance of the item 20 (from the reader 10) and its relative movement. The preferred method is a low power, low cost spread spectrum radar sensor (see articles in EE TIMES, April 18, 1994, page 36; and Popular Science, March 1995, pp. 107 - 117). This radar sensor allows accurate detecting of the presence, position, and movement of an item to be scanned. The radar sensor 50 is arranged to sense the position and movement of objects which are in the field of view of the optical symbol reader head 70. Preferably, the sensor 50 or control function apparatus 60 includes a range gate

which is set to sense objects which are within or near the reading range of the reader head 70. For use in installations having multiple readers in close proximity, means should be included to reduce interference between the object sensors on nearby readers, including (a) the use of low emitted power from the radar or lidar, (b) directional antennae, (c) differing spread spectrum sequences, (d) differing wavelengths of the emitted signals, (e) or coding of the pulse shape or data content of the emitted signals to make them distinguishable. An alternative embodiment uses lidar (optical radar) rather than radar.

Another alternative object sensor employs ultrasonic acoustic emitters and detectors. The ultrasonic implementation provides range and movement data, but is generally less effective for positional location of objects than the radar or lidar implementations, due to the longer wavelength of the acoustic signals, as compared to the electromagnetic signals used in the radar or lidar implementations.

Another means for sensing item location and movement comprises a sensing system using Doppler motion sensing based on detecting modulation at a known frequency which has been placed on the emitted scanning light beam in a flying spot scanner, and detecting the change in modulation frequency in the light reflected from the object. Doppler sensing of the change in frequency of the returned light itself could be used, but it is currently more cost effective to detect a Doppler shift in a modulated signal, due to the high cost of the optical mixing components used in a system which detects a Doppler shift in the light itself, compared to the mixer and/or frequency measurement components used to detect Doppler shifts at the audio or radio frequencies which can be used in a modulated system.

In a system using a scanning light beam or a scanned field of view of an imaging device, the direction of the scanning device at the time an object was detected can be used to indicate the direction of the object. If the

system emits light beams toward an object from several apparent sources, or captures images from several directions, the location of an object can be determined using triangulation or a similar process. For example, in a multi-window or multi-scanner application, the data reader can be provided with means to distinguish between return signals being received. Referring to Figures 5-6 by way of example, a multi-window scanner 200 such as the Spectra-Physics Magellan™ scanner is illustrated of the type disclosed in U.S. Patent No. 5,475,207, herein incorporated by reference. The scanner 200 has first and second windows 202, 204 through which different sets of scanning beams are passed.

As illustrated in the example of Fig. 6, a visible laser diode 535 generates an optical beam 515 which is collimated and directed toward beam splitter 538. The beam splitter 538 splits the optical beam 515 into a first beam 517 and second beam 518. The first beam 517 is directed to a fold mirror 536 which reflects the beam 517 through a central lens focusing portion 533 in lens 532 and to rotating optical polygon 530. The optical polygon 530 includes three mirror facets for producing three different scan lines scanning the optical beam across the pattern mirrors. The portion of the scanning beams returning through the first window 202 reflect back off the facet wheel 530 and are collected by collection optics namely collection lens 532, collection folding mirror 531 and analog PCB with photodiode 537. The portion of the scanning beams returning through the second window 204 reflect back off the facet wheel 530 and are collected by collection optics namely collection lens 540, collection folding mirror 544 and analog PCB with photodiode 546. One means to distinguish comprises employing separate detectors 537, 546 such that system determines that signal detected by the first detector 537 has entered through window 202 and signal detected by the second detector 546 has entered through window 204.

Fig. 7 illustrates an alternate multi beam system 220 having a rotating polygon mirror 230. A beam generator 276 generates a beam of light and directs it toward mirror 274. The beam generator 276 may be a laser, laser diode, or any other suitable source. The mirror 274 directs light toward the polygon mirror 230. As the polygon mirror 230 rotates, the outgoing beam is directed across a lower mirror array (not shown) and through the first window 202 to achieve a desired scan pattern. Light reflecting off the target returns via the same path and is collected by a collection mirror 272 and focused onto a detector 279.

Simultaneously (or intermittently if desired) to the operation of the first beam generation, a second beam generator 256 generates a beam of light and directs it toward mirror 254. The beam generator 256 may be a laser, laser diode, or any other suitable source. The mirror 254 focuses and reflects light toward the polygon mirror 230. As the polygon mirror 230 rotates, the outgoing beam is directed across the a mirror array (not shown) and then reflected out through the second window 204 to achieve a desired scan pattern. Light scattered off the target returns the same path and is collected by a collection mirror 252, reflecting off fold mirror 258 and focused onto a detector 259.

As shown, the reading beams may be generated either by first and second beam generators (e.g. laser diodes 256, 276 in Fig. 7) or a single generator (such as a single laser diode 535 and a beam splitter 538 of Fig. 6). There are several means for distinguishing. One example comprises employing separate detectors (as in the embodiments of Figs. 6 or 7). Another example comprises selecting beam characteristics of the first and second beams such that the beams can be distinguished by the detector. Alternately, the system may multiplex the beams, having only one of the beams on at any given instant. In another

example, the reading beams may have different frequencies which can be discerned by the detector.

Knowing the beam source for the signal detected (i.e. through which window or from which direction the scanning beam came) provides directional data from which the system can determine positional location of the object.

Another method of determining object location of the object is to record which scan line of a multi-line scan pattern was active when data was scanned indicating the presence of an object. For example, as bar codes, portions of bar codes, or other signals from the surface of the object are scanned, the scanned data can be tagged with the identity of the scan line active at the time the signal is received.

The presence, direction of movement, speed, and location of objects near the reader can also be sensed by using auxiliary light beams and detectors which are not necessarily used for reading the optical symbol. The light beams may be arranged such that beams are blocked as an object passes by, with a means of sensing the presence or absence of a light beam on a detector. In order to reduce interference from ambient light, it is preferable to modulate the light beams at some rate and detect the presence or absence of the modulated light beam at the detectors. A variation on this method detects the presence of an object by sensing light reflected from the object, rather than detecting the blockage of a beam by the object.

In another embodiment, the distance to the symbol may be estimated based on the characteristics of the detected symbol data signal and the known system transfer function (system step response) characteristics of the reader. This system may be used in conjunction with the system mentioned above of using the direction of the scanning device at the time the object was detected to determine the direction and location of the object.

In a system which has a periodic imaging or scanning function, changes in the image from frame to frame, or changes in the scanned data from one set of scan lines to the next can be detected and used to note the presence, location, and movement of objects within the field of view of the reader. Such systems may include readers using video imaging, readers using one dimensional CCD devices, and flying spot readers with one or more scan lines.

Using the item location and/or movement information from sensor 50, the control function apparatus 60 can control the operation of the signal processing and symbol decoding apparatus in the reader head 70 to improve (or adjust) various portions of the reader's operation. These adjustments may include (a) giving preference to a portion of the reader scan pattern, or (b) in a multiple head/window reader, giving preference to the reader head/window associated with the area where the item is located, (c) allowing the reader to adjust its signal processing to compensate for any distortion expected in the scanned data due to the particular area of the scan pattern where the item is located. This compensation may be based on predicted distortion values, or on distortion values measured for various zones of the scan pattern at some previous time and stored for use during the actual reading. For example, a particular flying spot laser scanner design may see a twenty percent growth of one module wide black bars for labels located ten inches from the scanner window measured along a scan line, decreasing linearly to a ten percent growth of a one module wide black bar for a label which is located five inches from the scanner window. Given this information describing the scanner characteristics, and knowledge of the distance from the window to a particular label being read, the bar widths measured during the scanning process can be corrected before application of the decoding algorithm, in order to increase the useable reading range of the scanner, and to be able to correctly read labels with printing

distortion which might otherwise have been undecodable due to the additional distortion added to the bar measurements during the scanning process.

Item movement information can also be used to distinguish between any scanner data obtained from moving objects and other data obtained from slowly moving or stationary objects, to allow the reader to ignore data from background objects, which can otherwise waste processing capacity or introduce misleading data which is apparently from a symbol. For example, in a UPC reader, if the presence of multiple items is detected, one or more of which are moving or have moved, and some of which are stationary, the measured bar/space data acquired when the imaging device or scanning beam is aimed at the moving or recently moving objects can be processed to attempt to read an optical symbol, and the measured bar/space data acquired when the imaging device or scanning beam is aimed at stationary objects can be ignored. The determination of which data should be used and which data should be ignored depends on the application and the environment around the reader, but in a typical application for a fixed mounted reader, the items to be read will usually move through the field of view of the reader, possibly with a pause in motion while near the reader.

Sensing that an item is present, even if it cannot be read, is useful for reader performance statistics, label quality statistics, theft detection, operator performance measurement and feedback for operator training.

A method for using item location information is shown in Figure 3. At step 100 the item location is ascertained. At step 110, parameters in the reader are adjusted based on the measured item location, followed by attempting to read an optical code symbol at step 120.

Figure 4 illustrates a method of using item position and movement information in a symbol reader which uses one or two dimensional image capture. At step 150 the item position and movement is measured. At step 160, the

illumination level and the image exposure time are adjusted for the best image quality possible for the measured item position and movement values. It is preferable to use the longest exposure time that will not have excessive movement of the image during capture, and to adjust the light level to achieve a good signal to noise ratio in the captured image at the selected exposure time. At step 170, an image is captured and analyzed to attempt to read an optical code symbol. This method is particularly useful in readers using either two dimensional or one dimensional imaging devices which can capture image data over some field of view during a controllable interval, such as a CCD imaging device with electronic shutter capability.

Certain types of distortion of the optical symbol data as received by the reader are a function of the distance from the reader to the symbol, and may also be compensated for if the distance is known. For example, in a laser scanner, the cross-sectional intensity of laser beam varies as a function of distance from the beam source, and the varying diameter of the beam results in varying amounts of convolution distortion in the detected signal. This varying beam diameter is difficult to avoid in a conventional laser system due to the nature of laser beam propagation, but the variation in diameter is predictable and so the resulting convolution distortion can be compensated for if the distance to the object and hence the beam diameter at the object is known.

Other distortions are a function of the location of the item within the field of view, and can be corrected more easily if the item location is known. For example, if the system uses an imaging optical system which produces an distorted image near the edges of the image field, the distortion can be corrected using standard image processing methods, which require a considerable amount of computation to correct an entire image. However, if the location of the item within the image field is known, the

amount of computation needed can be reduced by only correcting the portion of the image containing the item.

Item motion data can be applied to image blur caused by item motion during image exposure, and for item tracking between successive image frames to or scan patterns. This tracking information is useful for helping to distinguish between multiple objects which may be entering and leaving the reader volume at various times, and for properly associating partial optical symbol data taken from several images or scans, in order to build up complete symbol data for an object after obtaining multiple scans or images of the object, possible with multiple objects present.

Thus, an adaptive code reader and method of reading have been shown and described. Though certain examples and advantages have been disclosed, further advantages and modifications may become obvious to one skilled in the art from the disclosures herein and the invention is not to be limited thereby except in the spirit of the claims that follow.

Claims

1. A method of controlling operation of a data reader comprising the steps of:

obtaining information on at least one of location and relative movement of an object to be scanned;

collecting scan data on the object;

processing the scan data;

adjusting scan data processing based on the information obtained.

2. A method according to Claim 1 wherein the step of adjusting scan data processing comprises compensating for distortion expected in the scan data due to an area where the object is located.

3. A method of controlling operation of a data reader comprising the steps of:

obtaining location and relative movement information of an object to be read;

adjusting an internal operational parameter of the data reader based on the information obtained.

4. A method according to Claim 3 further comprising using radar for obtaining the information.

5. A method according to Claim 3 further comprising using lidar for obtaining the information.

6. A method according to Claim 3 wherein the step of obtaining information comprises sensing location of the object in a scan volume during at least two different time intervals, comparing locations of the object from the time intervals.

7. A method according to Claim 3 wherein the step of obtaining location and relative movement information comprises reading a scan volume from multiple read direc-

tions and wherein the step of adjusting an internal operational parameter comprises giving preference to the read direction associated with a portion of the scan volume where it is determined that the object is located.

8. A method according to Claim 3 wherein the step of adjusting an internal operational parameter is selected from the group consisting of

giving preference to data from moving objects over data from stationary or slowly moving objects;

adjusting the object illumination level; and

adjusting image exposure time.

9. A method according to Claim 3 wherein the step of adjusting an internal operational parameter comprises

giving preference to data from a certain portion of the reader scan pattern.

10. A data reader comprising

an optical code scanning device for scanning an optical code on an object to be read;

sensor means for obtaining information pertaining to movement of the object relative to the reader;

means for adjusting operation of the optical code scanning device based upon the information obtained by the sensor means.

11. A data reader according to Claim 10 wherein the sensor means is selected from the group consisting of: a radar sensor; a low power, spread spectrum radar sensor; a lidar sensor; a Doppler motion based sensor; ultrasonic emitter and detector.

12. A data reader according to Claim 10 wherein the sensor means is selected from the group consisting of: a video imaging sensor; a laser and optical detector.

13. A data reader according to Claim 10 wherein the optical code scanning device is selected from the group consisting of: a laser scanner; a flying spot laser scanner; a CCD scanner.

14. A data reader according to Claim 10 further comprising means for reducing interference between sensor means from nearby readers.

Fig. 1

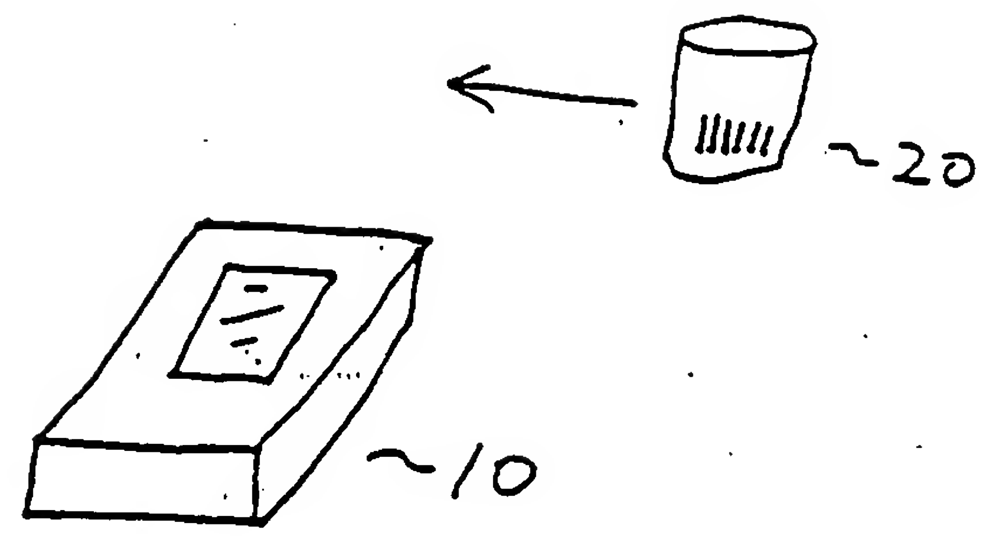
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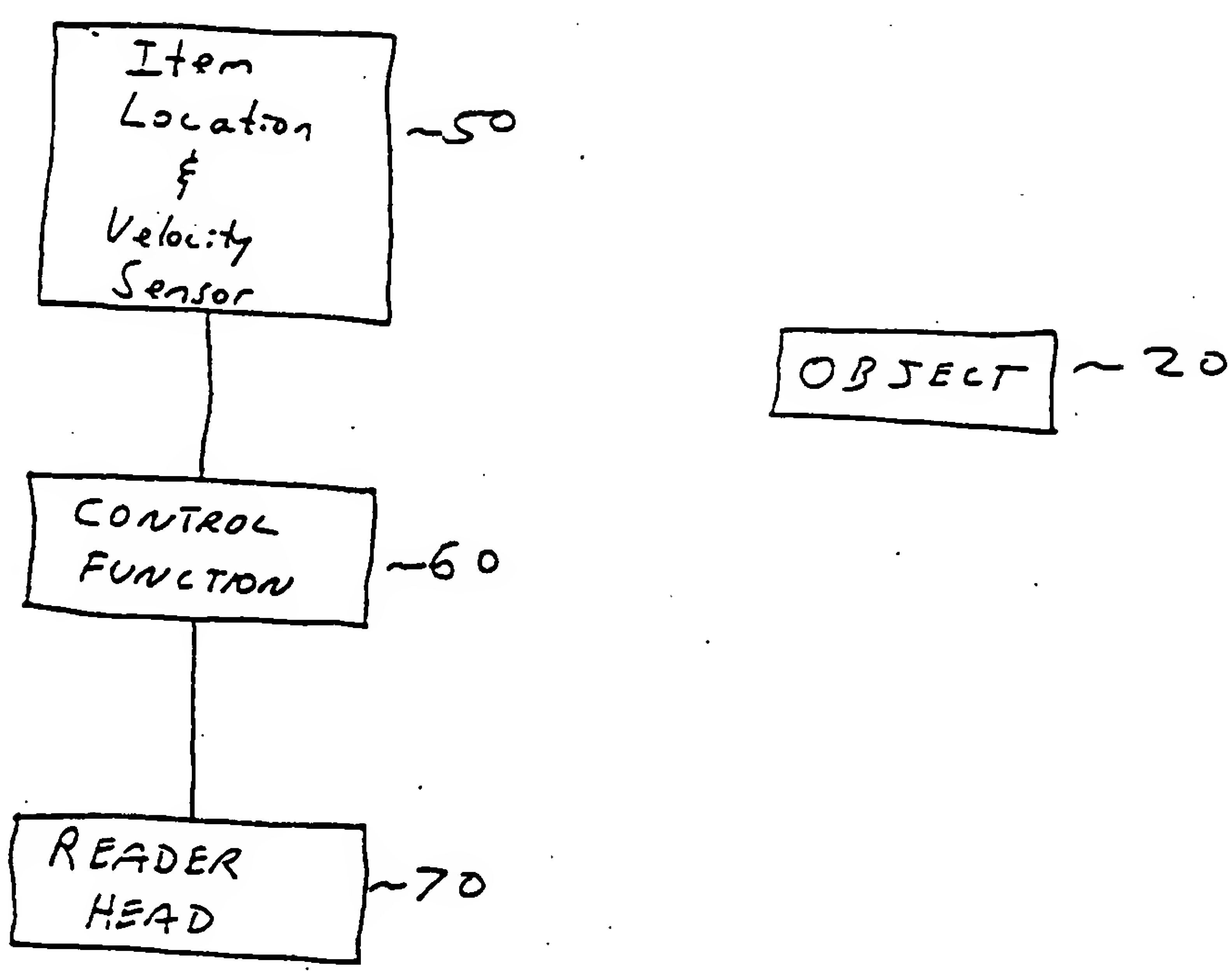
Fig. 2


Item Location & Velocity Sensor
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CONTROL FUNCTION
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READER HEAD
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OBJECT
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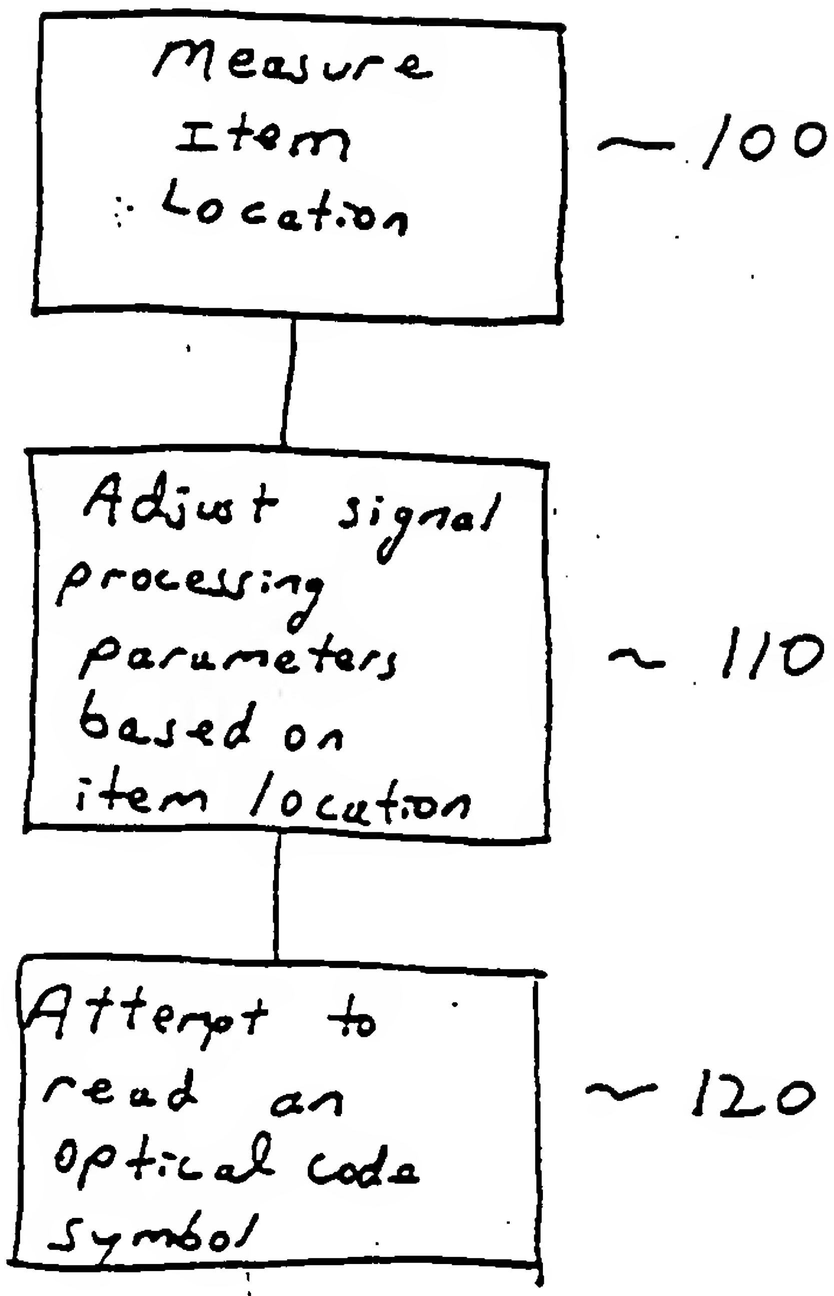
Fig. 3



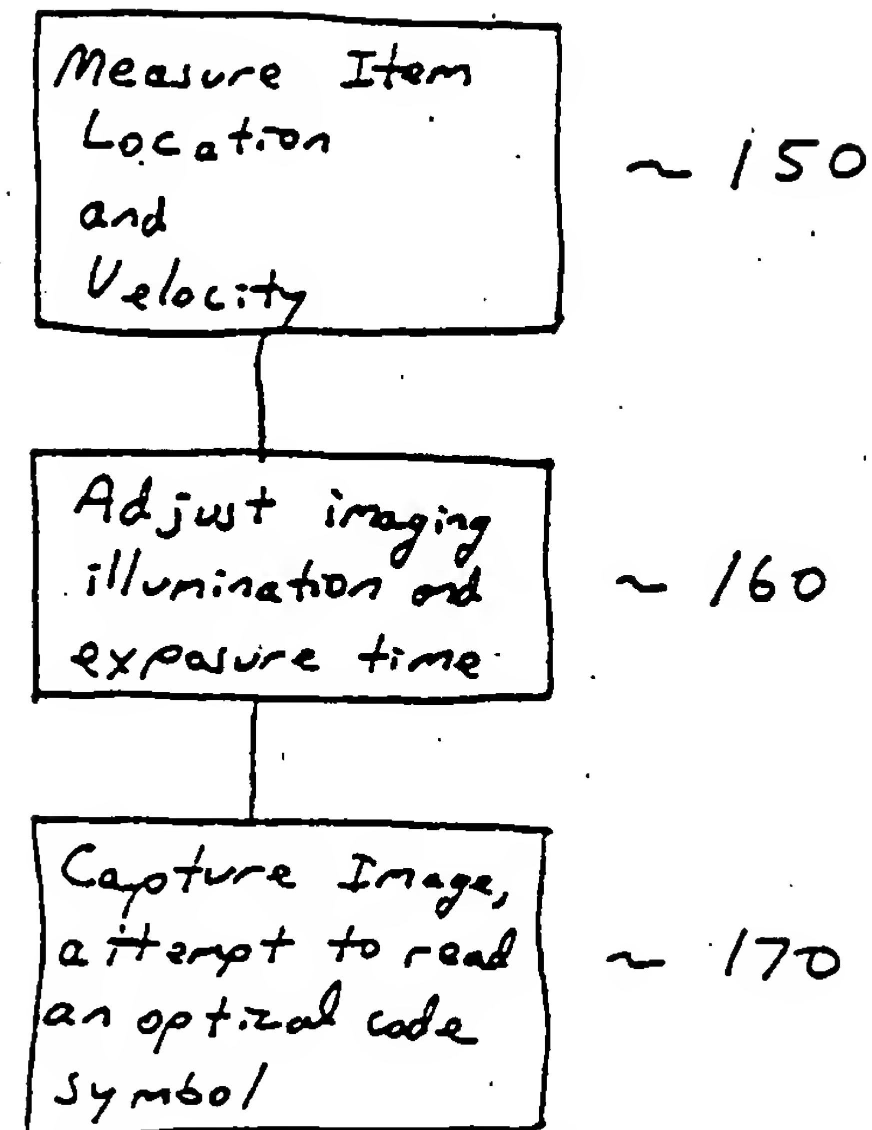


Fig. 4

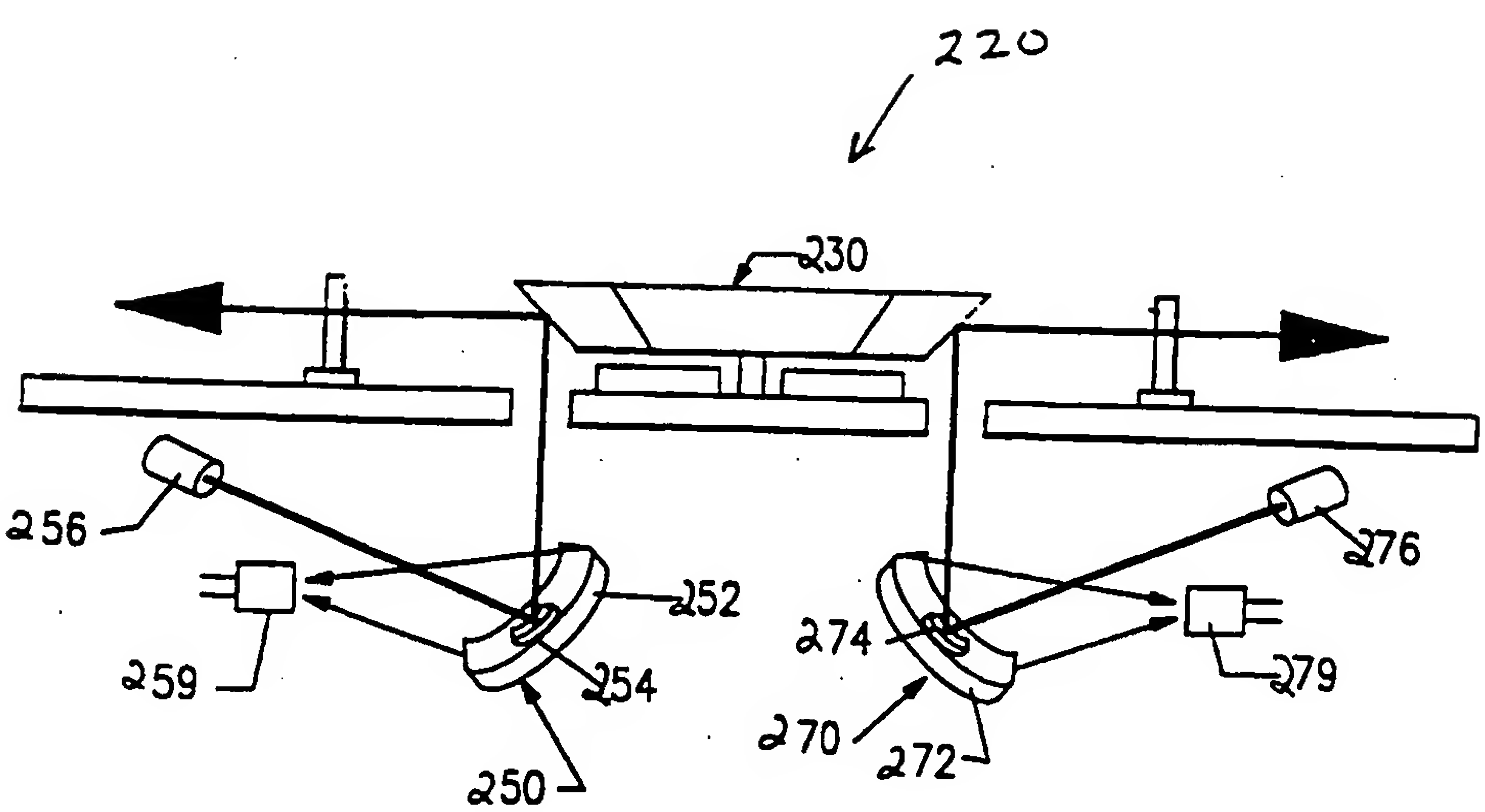


Fig. 5

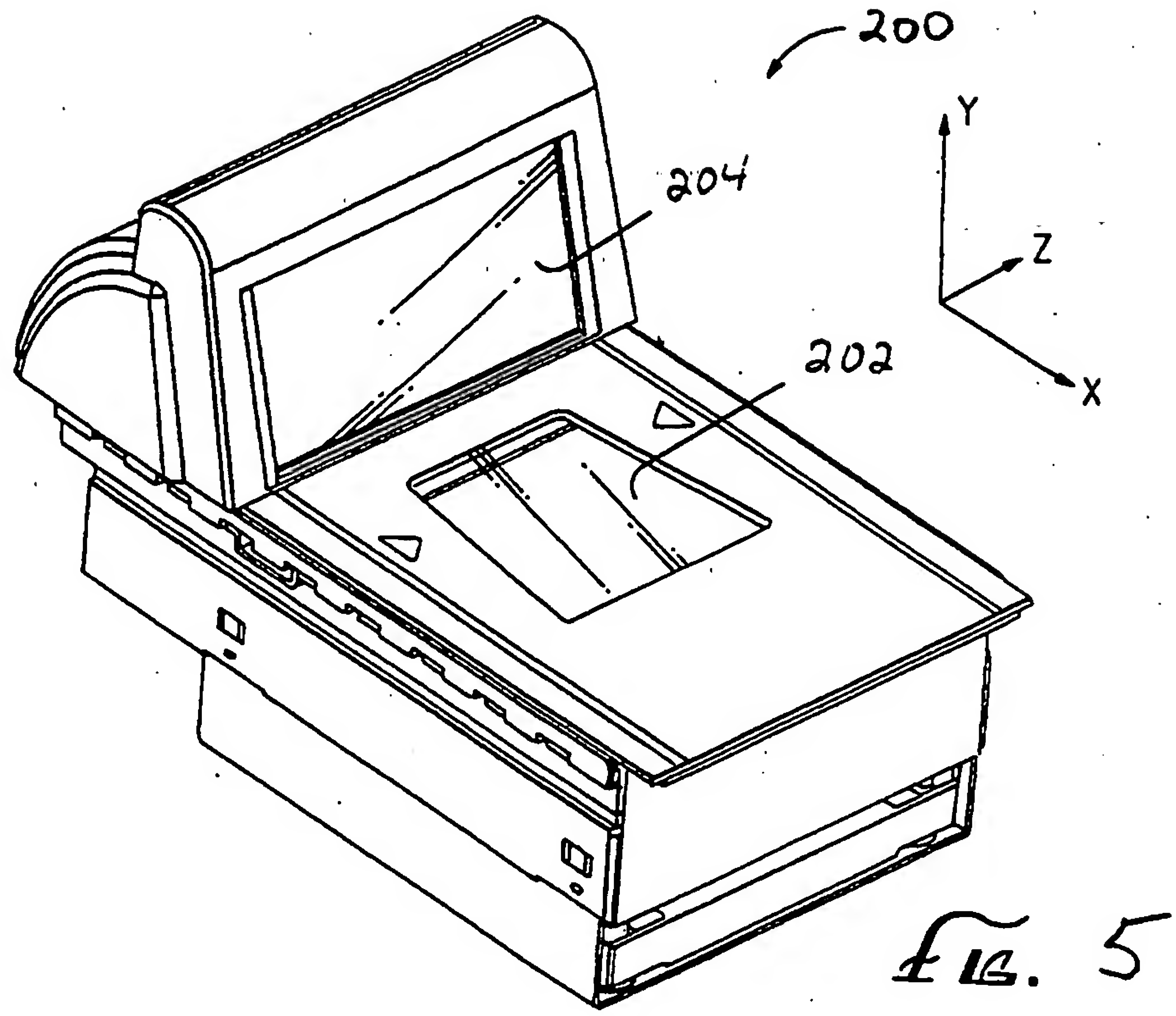

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FIG. 5

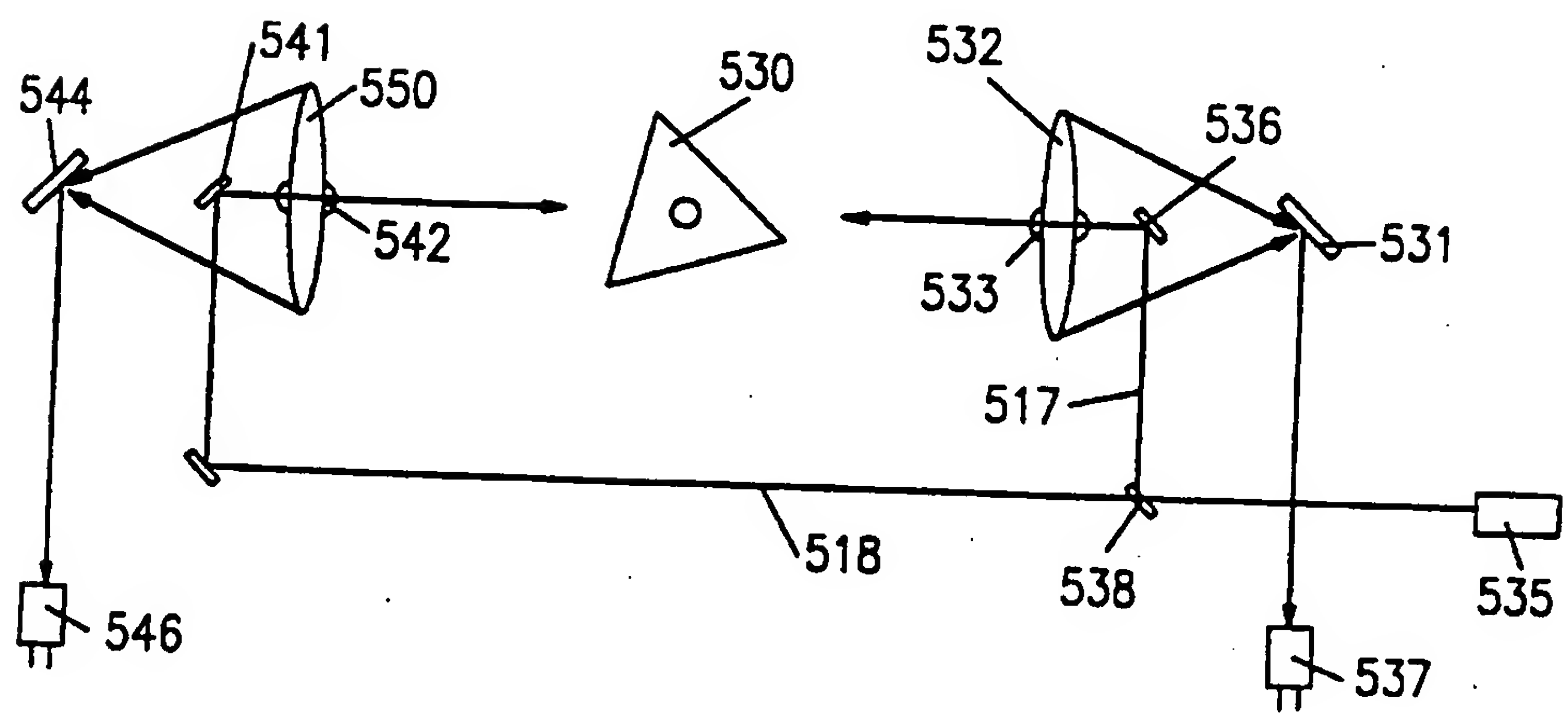
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FIG. 6

INTERNATIONAL SEARCH REPORT	International application No. PCT/US96/09956

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G06K 7/10
US CL :235/462, 454, 455, 459, 467, 470, 472, 476, 477; 250/201.2, 203.7, 206.1, 206.2, 235, 555, 557
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 235/462, 454, 455, 459, 467, 470, 472, 476, 477; 250/201.2, 203.7, 206.1, 206.2, 235, 555, 557

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 5,327,171 (SMITH ET AL) 05 July 1994, whole document	1, 3, 8, and 10-13
Y	US, A, 5,347,121 (RUDEEN) 13 September 1994, whole document	1, 3, 8, and 10-13
Y	US, A, 5,256,864 (RANDO ET AL) 26 October 1993, whole document	1, and 3-13
Y	US, A, 4,432,912 (DICKSON ET AL) 14 February 1984, whole document	1, 3, and 8-13
Y	US, A, 5,359,404 (DUNNE) 25 October 1994, whole document	1, 3-8, and 10-13
Y	US, A, 5,308,962 (HAVENS ET AL) 03 May 1994, whole document	1, 3, 8, and 10-13

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/09956

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 3,517,167 (BELL) 23 June 1970, whole document	1, 3, 8, and 10-13
Y	US, A, 5,287,271 (ROSENBAUM) 15 February 1994, whole document	1, 3, 8, and 10-13
Y	US, A, 5,216,230 (NAKAZAWA) 01 June 1993, whole document	1, 3-8, and 10-13
A	US, A, 5,311,999 (MALOW ET AL) 17 May 1994, whole document	7
Y	US, A, 4,958,064 (KIRKPATRICK) 18 September 1990, whole document	1, 3, 8, and 10-13
Y, P	US, A, 5,430,282 (SMITH ET AL) 04 July 1995, whole document	1, 3, 8, and 10-13
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INTERNATIONAL SEARCH REPORT

International application No.
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B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

APS
search terms: (bar code or upc) and (reader or scanner), optical, (moving or convey?), object detect?, radar, ultrasonic, emitter and detector, detector, ccd, (laser or led), processor, digital, adjust?, level, time, pattern, optical(p)scann?, illumination, 235/clas and camera and adjust?, convey, radar detector, radar gun, sensor and optical